

Data Analysis and Modeling to Support NOWCAST and Forecast Activities at the Fallon Naval Air Station

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LONG-TERM GOALS

The goals of this project are to increase our understanding of weather predictability and to develop capabilities to provide more accurate forecasts and nowcasts in complex terrain using ensemble modeling techniques and special observations including remote sensing.

OBJECTIVES

The main objectives of the study are: 1) To develop and test a mesoscale forecasting system with sub-kilometer horizontal resolution to support the NOWCAST system at the Fallon Naval Air Station (NAS); 2) To improve the accuracy of the forecasts and nowcasts by assimilating asynchronous data into the forecasting system; 3) To provide short-term accurate predictions of cloud structure, especially for clouds such as the stratus cloud decks and fog that are relevant to visibility for the Navy's aircraft operations in the complex terrain; and 4) To develop methods of mesoscale ensemble forecasting to improve the applicability of the forecasts and nowcasts.

APPROACH

A self-sustained MM5 real time forecasting system to support NAS Fallon was fully developed and tested. The system is now in continuous operation on a multi-processor computer located in the Division of Atmospheric Sciences at the Desert Research Institute (DRI). The system results - 24 hour forecasts updated every 12 hours - are posted on the dedicated web site with password protection [URL: <http://www.adim.dri.edu/>]. The forecasts are provided for five interactive domains with the highest sub-kilometer resolution (333m) on the innermost domain centered on the NAS Fallon runway.

- To increase the accuracy of the forecasts, three types of data assimilation were incorporated into the operational forecasting system:
 - Assimilation of data from four meteorological stations that were set up in the NAS Fallon area during a previous ONR project.
 - Assimilation of WSR 84 Fallon radar data.
 - Assimilation of satellite data and use of these data as input to a new methodology of improving model initial conditions in the vicinity of the NAS Fallon area and the initial boundary layer height over the entire model domain (Vellore et al. 2007).

The major testing of the forecasting system included sensitivity studies using various optional physical parameterizations, varying horizontal and vertical resolution, a varying number of processors used for the operational forecasting.

An online verification system has been developed in which a user can select a particular forecast from 24 hours or earlier, from one of the four Fallon stations and get a comparison of the predicted air temperature, wind speed and direction and measured at that station.

Another type of continuous evaluation was also developed. GOES visible (daytime) and infrared (nighttime) images and data are being continuously transferred from the NRL site to the DRI computer system. Besides being used for the data assimilation, the satellite images are being operationally compared with images of the cloud liquid water.

Installation of the sonic anemometer at the Fallon station B17 allows for verification of various turbulence parameterizations in MM5 and later in WRF and COAMPS.

This project provided a baseline for testing ensemble forecasting and a testbed for future inclusion of the WRF and COAMPS as preparation for future multi-model ensemble forecasting

Dr. Darko Koracin (P.I.) was responsible for the real time mesoscale modeling system design, model evaluation, and development and testing of the lag forecasting.

Dr. Melanie Wetzel (co-P.I.) was responsible for satellite data assimilation and verification.

Dr. John Lewis (co-P.I.) was responsible for data assimilation techniques and development of the lag forecasting methodologies and verification.

WORK COMPLETED

To support real-time forecasting and nowcasting at the Fallon Naval Air Station, surface meteorological stations were operational during the project period. The location specifications of these sites are:

- Fallon 31ESE [NAS B17] at Centroid in Fairview Valley (39°19'27" N, 118°13'22" W, 4235' MSL). Location from NAS Fallon: 23 miles range at 99 degrees azimuth.
- Fallon 23SSE [NAS B19] at Blowing Sand Mountains (39°08'31"N, 118°40'01"W, 3886' MSL). Location from NAS Fallon: 16 miles range at 164 degrees azimuth.
- Fallon 36NE [NAS B20] at Carson Sink (38°54'40" N, 118°23'14" W, 3881' MSL). Location from NAS Fallon: 31 miles range at 13 degrees azimuth

- Fallon NAS EW71 Complex at Edwards Creek Valley (39°31'57" N, 117°44'50" W, 5192' MSL). Location of EW Complex: 11 miles NE of Cold Springs, NV

The four Fallon NAS sites have operated continuously during the past year except for one equipment malfunction at the Centroid site (B17). In early March 2008, a wind storm damaged one of the tower guy wires and the tower tipped over and damaged the ceilometer. Temporary repairs were made to get the station operational again. Permanent repairs to the ceilometer will be done this fall, involving returning the ceilometer to the manufacturer for repairs and recalibration. Replacement of the bent tower section will also be done this fall.

Realtime data recovery rates are usually 95% or greater. During maintenance visits, data is retrieved from memory and later loaded to the database. This increases the data recovery to more than 99%. Maintenance visits are performed twice annually at all stations. Additional maintenance visits to the Centroid site are performed monthly to retrieve data from the sonic wind sensor and for maintenance cleaning of the ceilometer surfaces. Maintenance visits consist, at minimum, of cleaning instrument surfaces, checking battery and power system conditions, verifying the functionality of all instruments, and data retrieval. Additionally, instruments are field checked against laboratory calibrated sensors to validate the measurements. Sensors with mechanically operating parts (wind vane and precipitation gauge) are checked for proper operation and free movement of moving parts.

The real-time MM5 system was developed and installed on an XD1 Cray computer at the Desert Research Institute. To account for synoptic processes and also to resolve the characteristics of the mesoscale processes, coarse and nested grids were set up to cover a large portion of the western U.S. The coarsest grid has a horizontal resolution of 27 km and encompasses most of the eastern Pacific Ocean and western United States; it has 103 x 103 grid points (23 synoptic sounding stations in the western and the central U.S. fall in this domain). The next grid has 103 x 103 points with a horizontal resolution of 9 km and covers Nevada and most of California, while the subsequent grids are each centered on Fallon, with resolutions of 3, 1, and 1/3 km. The third grid was of horizontal dimensions 103 x 103, while grids 4 and 5 were both comprised of 49 x 49 points. Each model domain consists of 40 layers, where 23 layers were in the lowest 3 km for forecasts that are significant to aircraft operations.

Software for assimilation of data from surface station, radar, and satellites was completed and incorporated into the real time forecasting system.

Online verification using MM5 forecasts and data from the four Fallon stations was designed and implemented.

RESULTS

MM5 real time forecasting results were evaluated using data from the special weather stations in the Fallon area. Figure 1 shows the comparison of the wind components as predicted by MM5 and as measured by the sonic anemometer at the Fallon station B17. Two turbulence schemes were tested: Gayno-Seaman and Eta PBL. While the model results with different schemes generally follow each other relatively closely, they are generally not able to reproduce the short-term extremes that are measured by the sonic anemometer. Consequently, it will be important to investigate the effects of

wind gustiness and methodologies to estimate the probabilities of wind gusts when using wind forecasts.

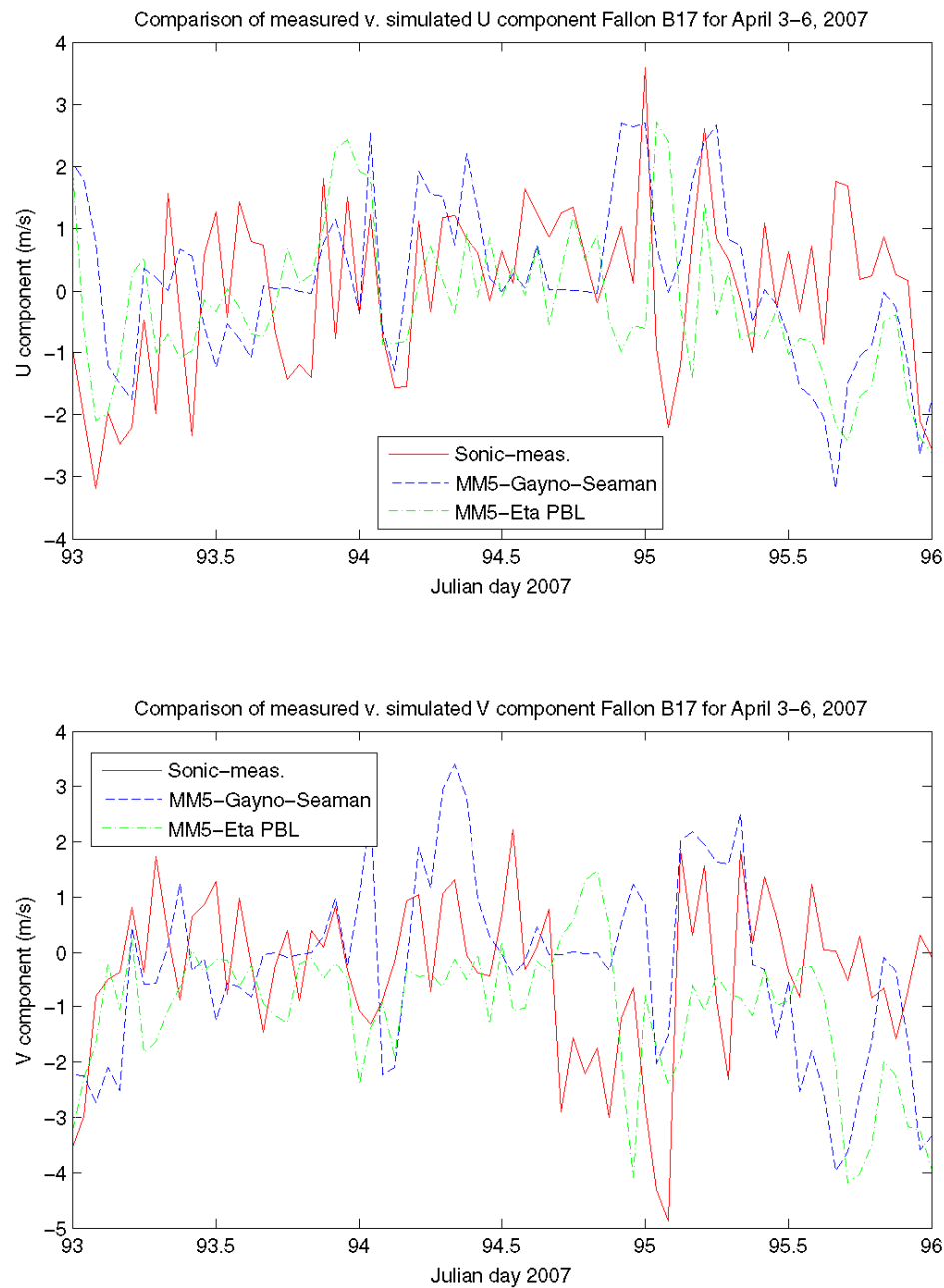


Figure 1. Comparison of the MM5 forecasting results for the u and v wind component with the sonic anemometer data at the Fallon station B17.

To monitor long-term model behavior and accuracy, we have developed an operational web-based system of model evaluation of the wind speed, wind direction, and air temperature at any of the Fallon stations. Figure 2 illustrates the evaluation for a winter and a summer case.

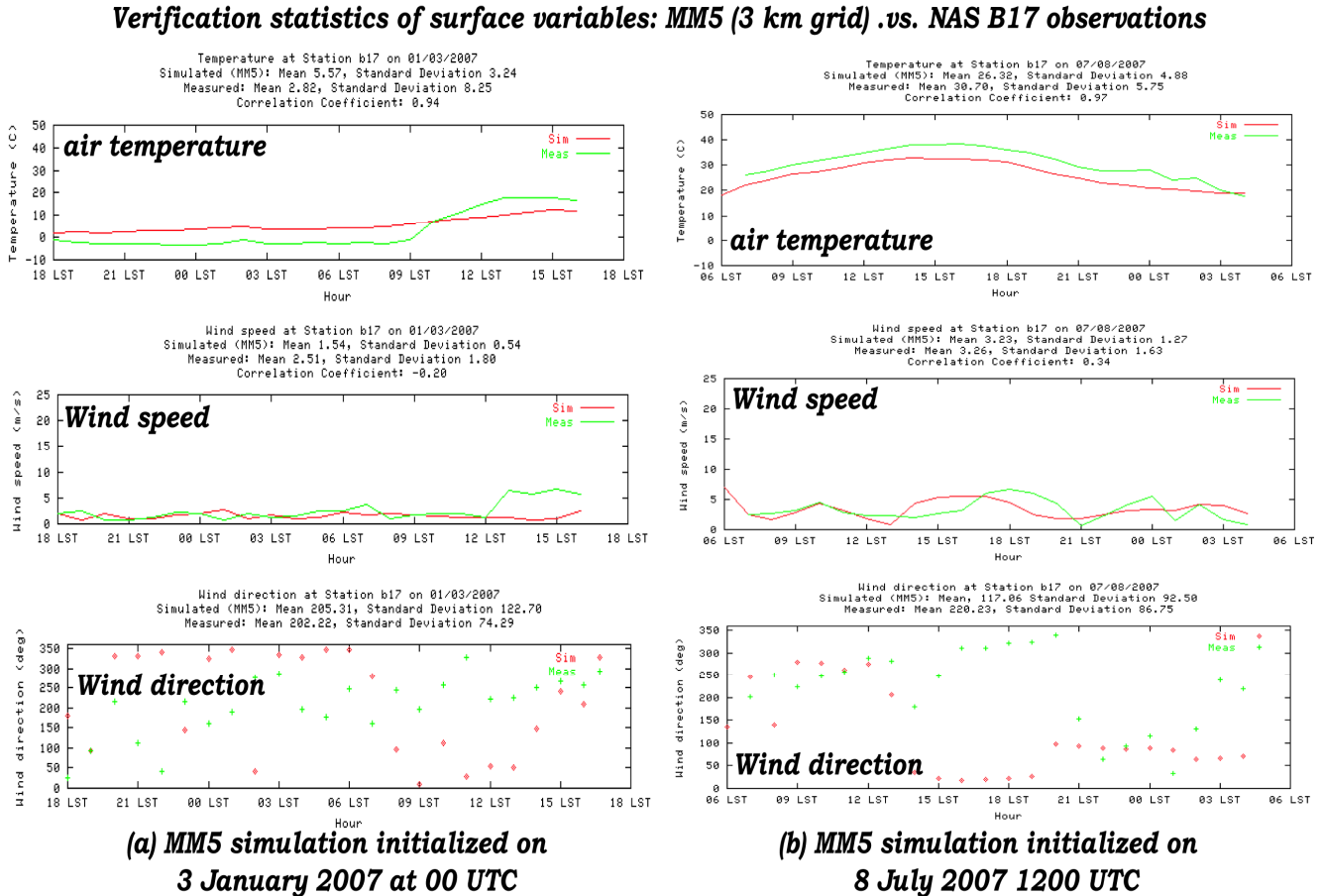


Figure 2. Example from the online real-time forecasting verification results for winter and summer case studies.

The results from the verification studies show the importance of having special weather stations available in the Fallon area.

The results from the developed online verification of the predicted cloud structure are shown in Fig. 3 for a case in the winter (Fig. 3) and a case in the summer (Fig. 4). This and other similar comparisons showed that the winter cases appear to be more difficult to forecast due to enhanced baroclinicity. This will be further investigated in our subsequent ONR project.

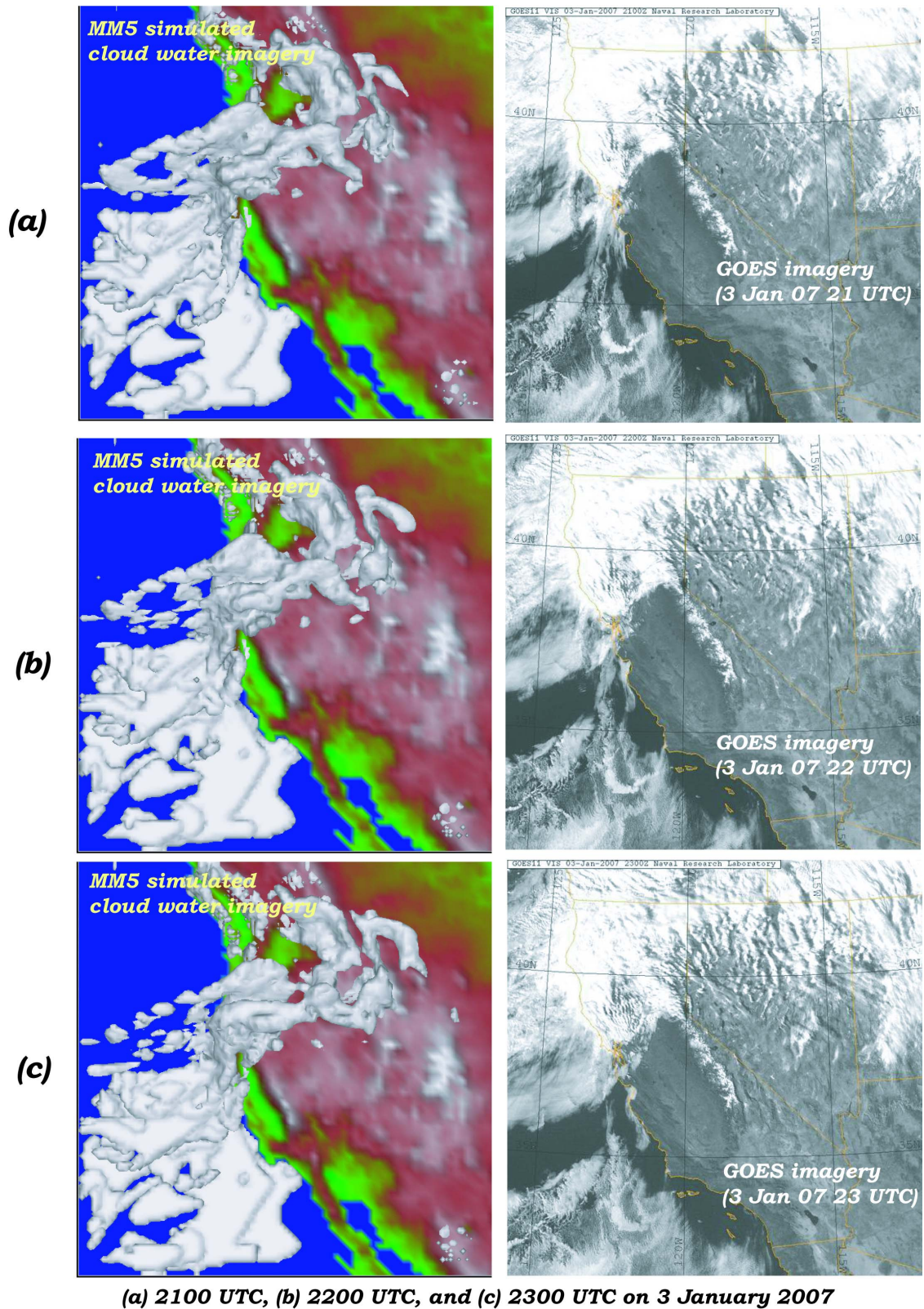
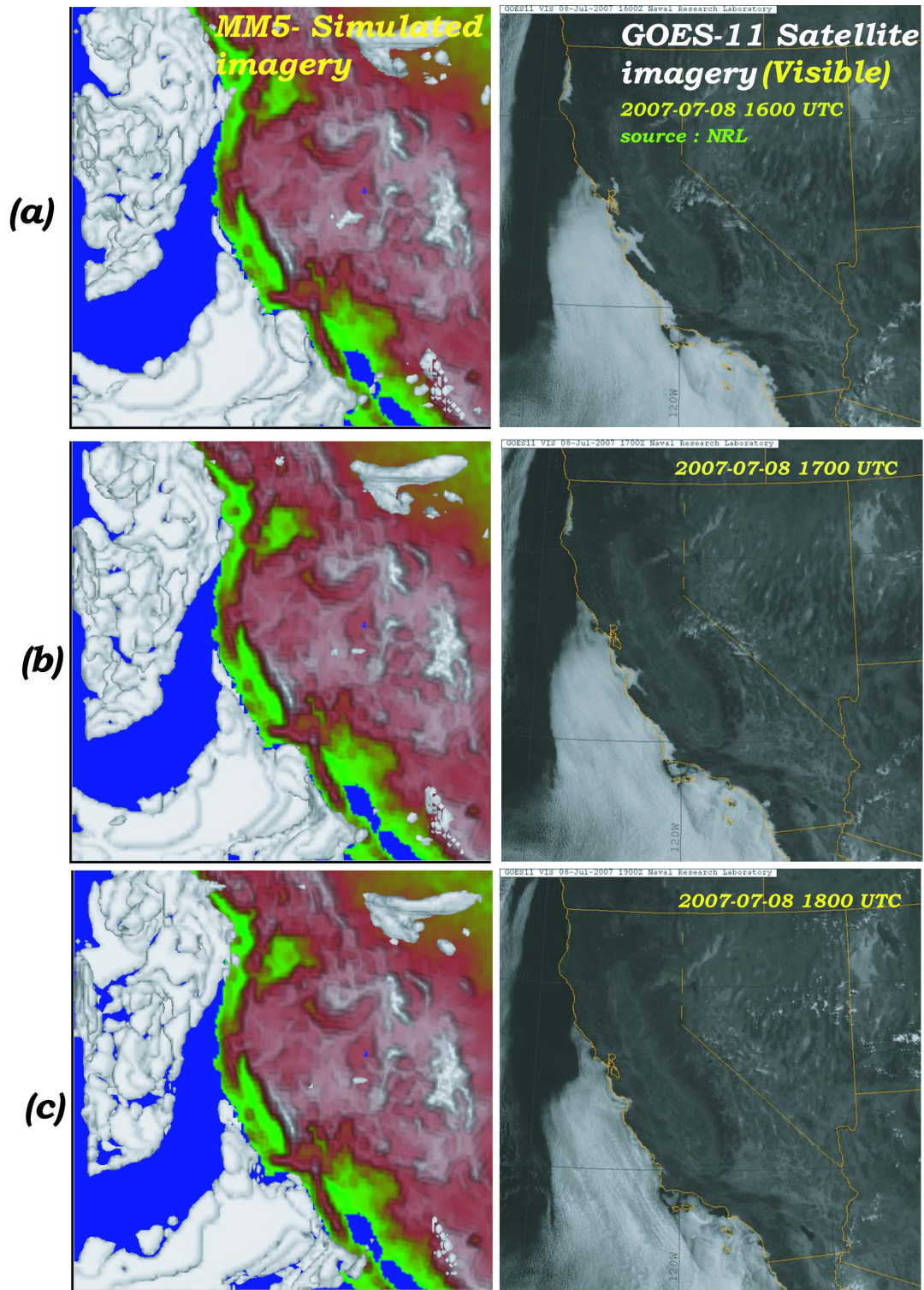


Figure 3. Example of online verification of the cloud structure as simulated by MM5 and compared to GOES images for a winter case.



Verification: MM5 simulated cloud water imagery obtained from 27-km grid

Figure 4. Example of online verification of the cloud structure as simulated by MM5 and compared to GOES images for a summer case.

Figure 5 shows results from our lag-forecasting experiment for the strong dust storm case in February 2002. The lagged forecasts were separated by the lead time and compared with the radiosonde results at 500 hPa for the geopotential, wind speed, wind direction and the air temperature.

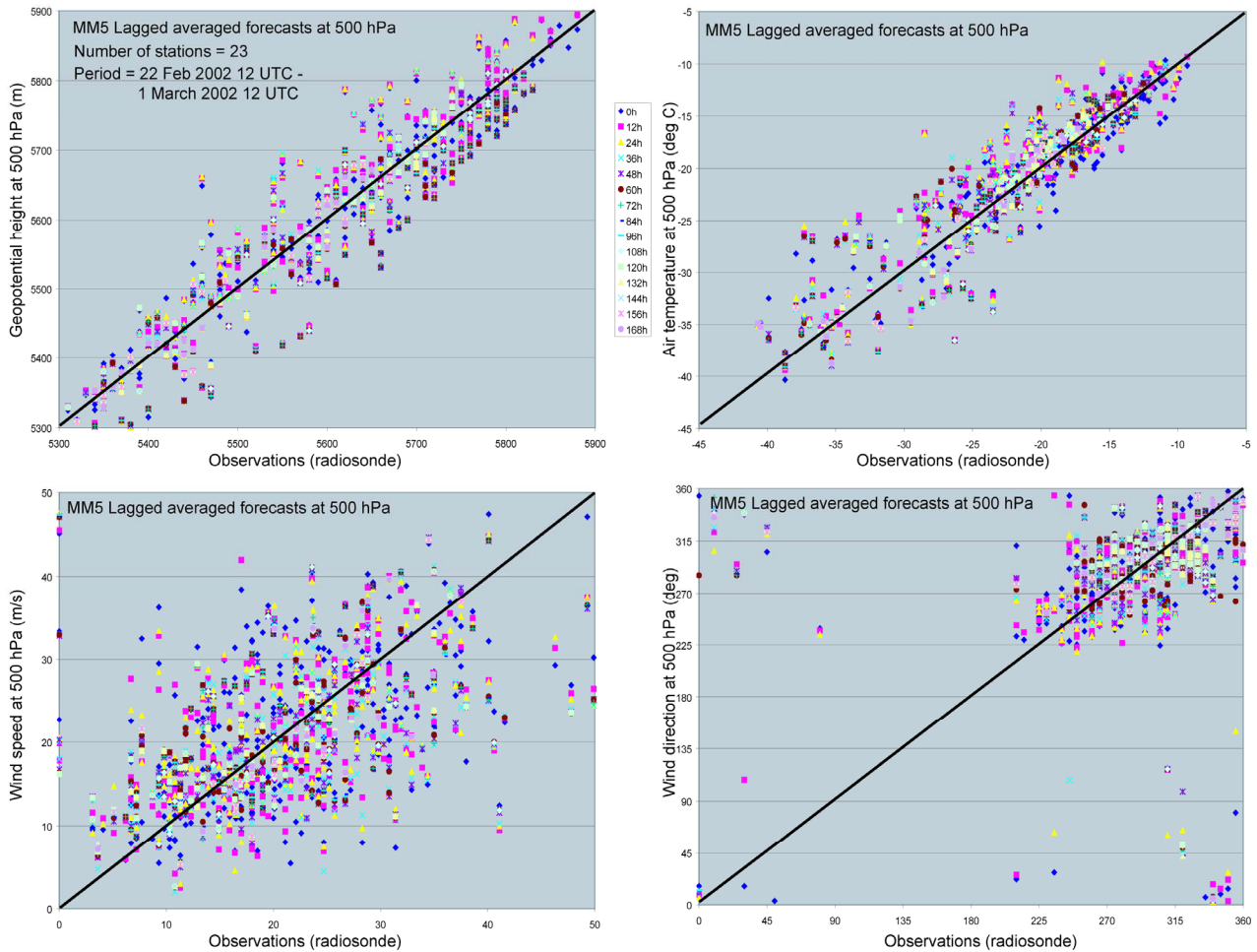


Figure 5. MM5 lagged forecasts for the geopotential, wind speed, wind direction, and the air temperature at 500 hPa compared to the radiosonde data for a storm case from 22 February to 1 March 2002.

There is no significant drop in correlation for the longer lagged forecasts. The figure clearly indicates that the lagged forecasts show noticeable skills and can be used to generate accurate ensembles. This will be investigated further in our subsequent ONR project.

IMPACT/APPLICATIONS

The results of this study will improve the predictability of high-resolution weather phenomena relevant to the Navy's operations, as currently applied to the Naval Air Station in Fallon, NV. However, the results and methodology of the multi-model ensemble mesoscale forecasting will significantly enhance the capability of accurate forecasts and nowcasts of winds, turbulence, cloud, fog, and visibility. This will aid

in decision making and in the performance of low-level airborne and sea-based naval operations. The results may be applied to other areas of interest worldwide.

RELATED PROJECTS

Dr. Koracin is a P.I. on a project supported by another ARO grant that is focusing on visualization and virtual reality applications of the Fallon NAS high-resolution mesoscale forecasts. Dr. Koracin is a co-P.I. on an ARO Project entitled “Forecasting of Desert Terrain” where real-time experience and expertise is facilitating an interdisciplinary project linking dust emission modeling, atmospheric predictions and Lagrangian Random Particle Dispersion modeling. Dr. Koracin is also a co-P.I. on a recently completed multi-institutional NSF-EPSCoR Project on Cognitive Information Processing: Modeling and Inversion where they are developing new methods of satellite data assimilation and investigation of predictability and chaos in numerical weather and climate forecasting (Vellore et al. 2007). He is also a lead investigator for a Climate Modeling component (global climate modeling and downscaling to regional, mesoscale, and microscale domains) of a recently awarded NSF-EPSCoR project focused on Climate Change.

PUBLICATIONS AND PRESENTATIONS

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